A Study On Cognitive Computing Methodologies For Intelligent Decision Making And Problem Solving

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Abstract: Cognitive computing is the field of study on intelligent computing which provides the computational intelligence by mimicking the process of brain. Decision making is a part of cognitive process in which a course of actions are chosen from the opportunities based on given criteria. Generally the decisions are made by the intelligent support system that have the potential to transform the human decision making capacity to systems with the help of fields like artificial intelligence, system engineering, machine learning techniques. This paper provides an insight on cognitive computing and its historical perspectives followed by various methodologies to implement algorithms in machine learning for intelligent decision making. Further, methodologies based on cognitive informatics models such as LRMA and OAR and the denotational mathematics for effective knowledge processing are also discussed. It also provides the information on visual analytics and cognitive analytics in which the conceptual view framework and its challenges are highlighted.

Index Terms: Cognitive computing, cognitive analytics, cognitive informatics, denotational mathematics, game theory, machine learning and visual analytics.

1. INTRODUCTION

Human brain has the versatile characteristics in taking decisions on its own and performing things according to the situations. Imagine a computer system that can perform the same functionalities as like human brain that can be termed as cognitive computing. Scientist and researchers are working on this field to make a computer that can think and act and emotionally connect to the situations. However they are able to achieve the feat in some systems that can perform actions similar to human brain, technically stated as artificial intelligence [1]. Further cognitive computing can be termed as an interdisciplinary approach which has its own share of artificial intelligence, psychology, philosophy and linguistic representation with intent to mimic the human brain in order to implement computational intelligence by cognitive inference and perceptions [2]. The evolution of cognitive computing starts from knowledge discovery which identifies the potentially useful information from various media based on the requirements of applications. Then we have the birth of interdisciplinary study called cognitive science which deals the formation of information and how it transcribed in brain that includes fields such as computer science, cognitive neuro science, psychology, linguistics ect., Another leap in the data processing comes in the form of big data where the characteristics of data such as velocity, variety and volume aretaken into consideration. In Cognitive computing, the intelligence depends on the data and it cognizes the potential of data which forwards to the computational intelligence. [3]

2 DECISION MAKING IN MACHINE LEARNING

Cognitive decision making is an information reasoning technique in which the outcome is based on matching the stored knowledge in problem solving. The steps in cognitive decision making are represented in Fig.1.1 [4].

2.1 Deciding on input-output training patterns

This step decides on which input and output training patterns that to be used for the decision making process and the data may be in the form of numeric values, class, or combination of both. Further these patterns will be used in extracting its features

2.2 Feature Extraction

Feature extraction will play pivotal role in machine learning and image processing. Which starts from the set of measured data and the features are built should be informative and non-redundant. In this process, it concludes the procedure to determine the input pattern for the suitable outcome. The corresponding examining will be done by field experts.

2.3 Creating structured information for machine learning

In this step, the random patterns will get a format that can be suitable for machine learning algorithm which can be done by finding missing values, normalization of patterns and sampling of information that can lead to a correct layout.

2.4 Apply machine learning techniques

The selection of machine learning technique based input and output feature is made and then the generalized model representation is created by involving the training pattern in the learning system. Some of the techniques available are decision trees, naive bayes, neural network, linear regression etc.

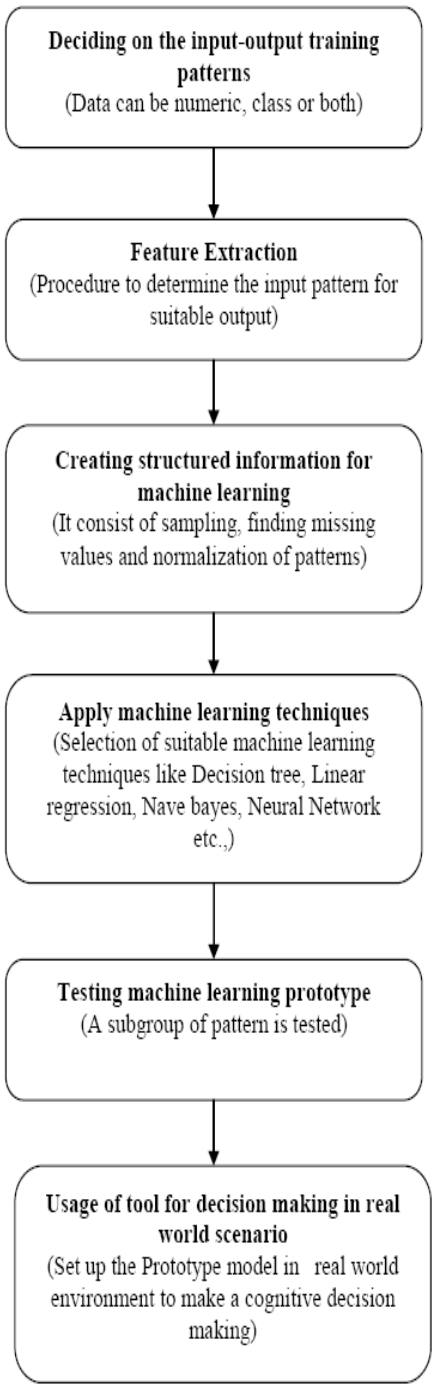

***Fig 1.2** Steps in cognitive decision making [4]*

2.5 Testing machine learning prototype

In this step, the subgroups of training patterns are tested and as a conclusion the decision making capability of prototype is measured quantitatively. The tested prototype should be a robust enough to train the different patterns.

2.6 Usage of tools for decision making in real world scenario

Once the testing of performance for prototype is made, then set up the prototype model in the environment and use it for the cognitive decision making for the real world problems.

3. THEORIES IN DECISION MAKING

Decision making is process which comprise of choice functions and strategies used to make a decision in given set of possibilities and different set of theories which gives different set of functions. The following are the some of the theories associated in decision making [5].

3.1 Game theory

Game theory is a study of mathematical models of conflict and cooperation between the decision making and it also depict as a science for making strategies or optimal decision making independently in a strategic environment. This game theory can be used in areas like economics, logics, psychology and computer science. In which the one gain the results in loss of other. Game theory gains a major role in science for logical decision making in human and computer systems.

The game theory for the decision problems can be modeled as triple,

$$d = (\Omega, N, M) \quad (1)$$

If an action $m \in M$ is choosed and the prevailing state is $\omega \in \Omega$, then a consequence will be $\alpha(\omega) \in N$. The utility functions can be defined for the action a can be defined as $p(m): M \rightarrow R$ and $u: N \rightarrow R$. Then the utility theory function (d) can be written as:

$$d = \{m \mid \Omega \; u[m(\omega)]p(m) = \max (\Omega \sum u[x(\omega)]p(x)) \wedge \; x \in \; M)\} \quad (2)$$

3.2 Bayesian theory

Bayesian theory is a statistical approach to problem of pattern classification. This approach makes use of statistical systems to quantify the tradeoff in decision making with use of its probabilities and the cost. In this theory the choice function is called as decision rule. A loss function L is used to evaluate the consequence of actions.

$$L: \Omega \times M \rightarrow R \quad (3)$$

Where Ω is the set of possible states of the nature, M is set of actions, Ω×M denotes the Cartesian product of choice.

By using Loss function the choice of decision making can derived as,

$$d = \{m \mid p [L (\omega, \alpha)] = \min x \in M (p [L (\omega, x)])\} \quad (4)$$

Where p [L (ω, α)] is the expected probability of loss for action xonω∈ Ω.

Despite the difference in the representations of the game theory and the Bayesian theory, both will be used for an optimal decision making in which the loss in Bayesian theory is equal to the negative utility in game theory. Thus the decision makers who are expecting the optimal decision can use the utility theory and the decision makers who seeks conservative decision can use the loss or risk based theory for a decision making [5].

4. METHODOLOGIES IN COGNITIVE COMPUTING FOR DECISION MAKING

The methods in cognitive computing are based on the theories associated with cognitive informatics and denotational mathematics [2], [1] and also we discuss on methods such as visual analytics and cognitive analytics in this section.

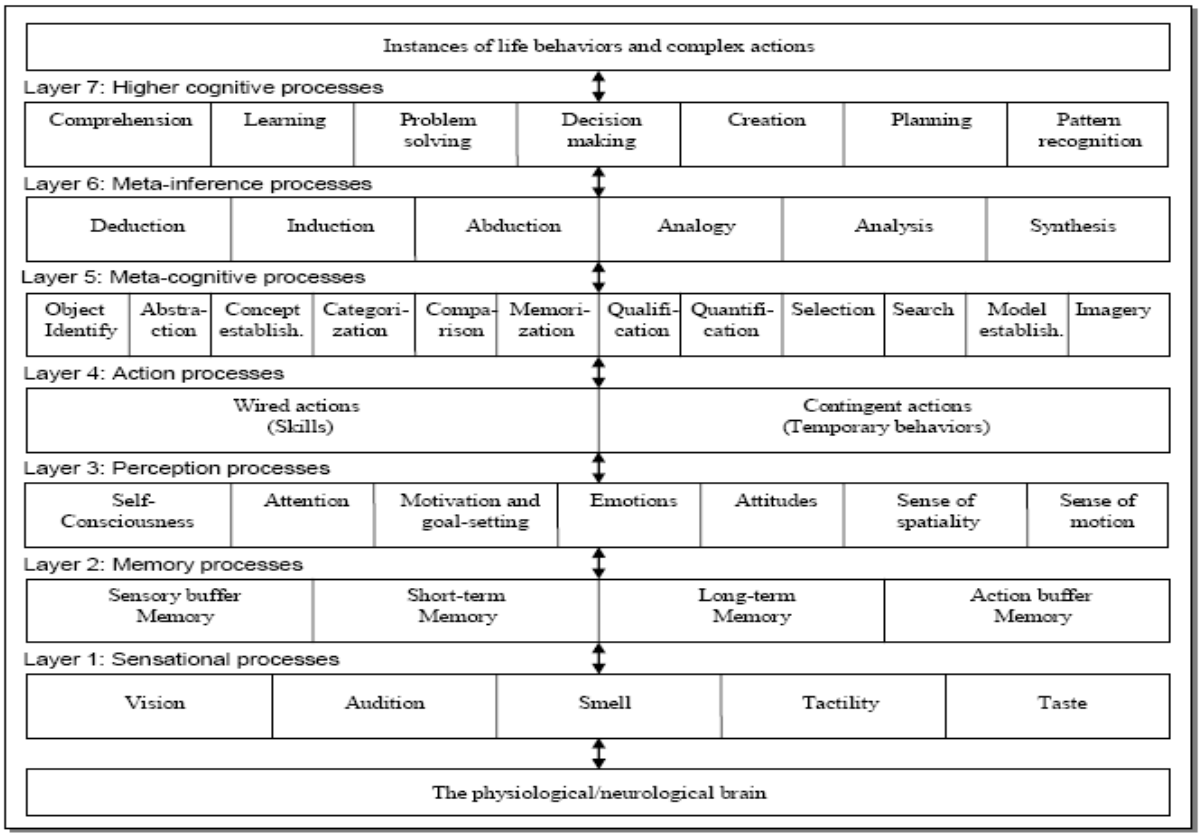

Fig. 1.2 Layered Referenced Model of Brain (LRMB)[2][1]

4.1 Cognitive Informatics

Cognitive informatics is the interdisciplinary field which consists of cognitive science and information science. Which process the human information in the basis of computer application and related computing [6] and also it's constitute of other fields like software engineering, artificial intelligence and neural psychology[7] for information processing. The Layered referenced model of brain (LRMB) in Fig.1.2 and Object-Attribute-Relation (OAR) model in Fig. 1.3 act as the base model for the architecture of the cognitive informatics. These model posses seven layers such as Sensational Processes, Memory Processes, Perception processes, Action processes, Meta-cognitive Processes, Meta-inference processes, Higher cognitive processes to implement the computational intelligence[2],[1]. The sensational processes in the layer 1 of LRMB model deals with the basic qualities of human such as vision, audition, smell, tactility and taste which gets the input signal from brain. from layer 1 the data is transferred to the memory processes layer and it comprise of Sensory Buffer Memory (SBM), Short Term Memory (STM), Long Term Memory(LTM) and at last Action Buffer Memory (ABM) where all the memories will receive and store in the form of information. The information gathered in layer 2 will be used in layer 3 for perceptions like self-consciousness, Attention, Motivation, goal setting, Emotions, attitudes, sense of spatiality and sense of motion where all the qualities provide foundation for the actions performed in the layer 4 with set of skills and temporary (contingent actions) behaviors. These actions results in a meta cognitive process with advanced qualities like comparison, selection, imagination, object identification, categorizing, searching. A meta Inference is made on the information gathered in previous layer by induction, analysis, synthesis and further the information is transferred to higher cognitive process where the conclusion is made with help of qualities like comprehension, problem solving and more importantly by using decision making and the resultant actions are performed effectively. The OAR model shows the relation among the attributes and objects which depicts the structure of information and knowledge passing in brain. The OAR model consist of object O1 and O2 which establish the connection between the object to object, object to attribute and attribute to attribute, where the connection is complicated.

4.2 Denotational Mathematics

Denotational mathematics is a mathematical structure that deals with the high level mathematics entities beyond numbers and sets. It also deals with aspects such as abstract objects, complex relations, perceptual information, intelligent

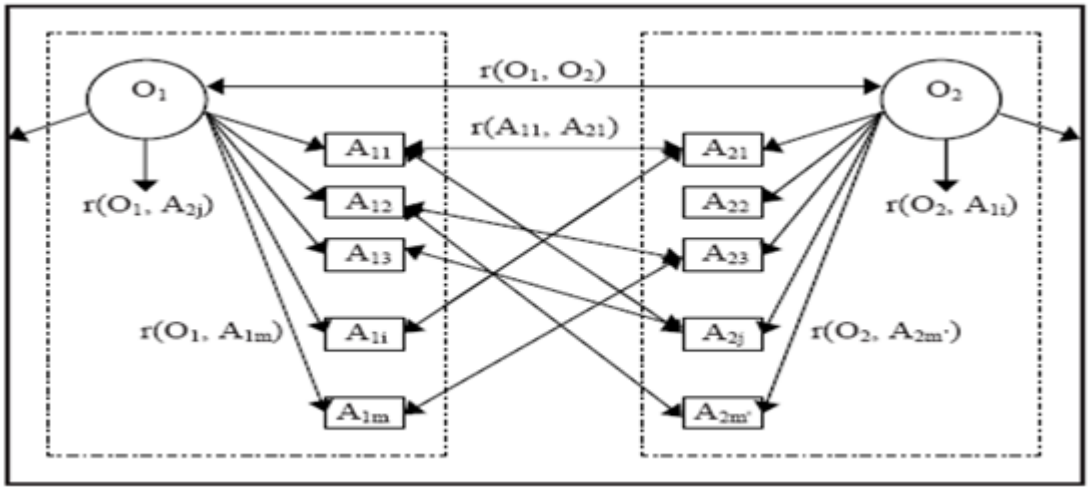

Fig 1.3 *Object-Attribute-Relation (OAR) model [2][1]*

behaviors, behavioral processes and systems [2]. It helps to design the architecture for intelligent systems and also provides solution for problems of computational intelligence and cognitive informatics. Denotational mathematics also acts as a effective tool for knowledge processing that can be used to solve the real world problems [1] Denotational mathematics uses the paradigms such as concept algebra, System algebra and Real time process algebra where all used for algebraic manipulations of abstract concepts [2] and provides the powerful modeling of cognitive decision making system [1].

4.3 Visual Analytics

Visual analytics is a new field that developed from data mining which posses the combination of quantitative capabilities of a computer system and the cognitive capabilities of a human to create knowledge. The data source for visual analytics is given from databases such as RDBMS, OLAP and through various social Medias to perceive the different knowledge. The characteristics like interactive exploration and visual manipulation plays a major role in visual analytics [8]. Visual analytics also explores and analyze the huge volume of information that used for the decision making that are complex [9]. SAS visual explorer is one of the web based exploratory application tool used for the handling big data by analyzing the data pattern and finding the anomalies in the data [10].

4.4 Cognitive Analytics

Cognitive analytics is evolved from the fields such as data mining and visual analytics. In cognitive analytics the need of human effort is removed from the process loop and the entire knowledge processing and decision making is automated. Fig 1.4 depicts the conceptual view of cognitive Analytics, where the data for cognitive analytics are comes from various sources which include structured, semi structured and unstructured data [8].

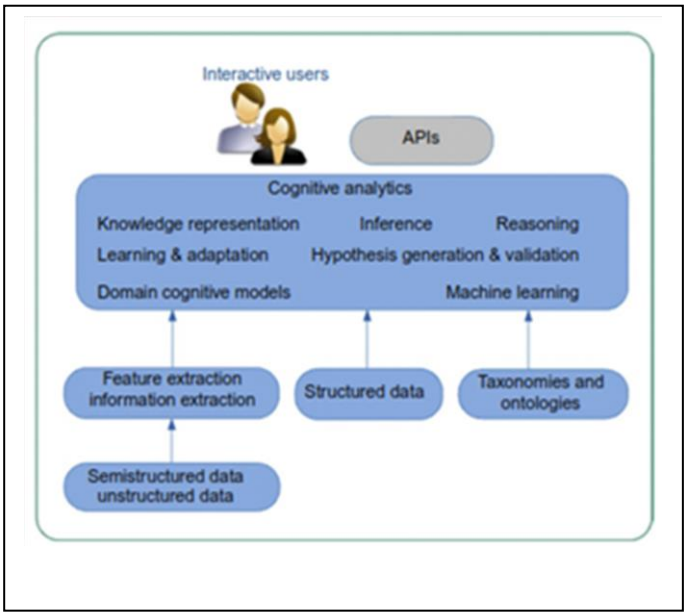

Fig 1.4 *Conceptual view of Cognitive Analytics [8]*

In order to enable the reasoning and inference for decision making, cognitive analytics employs the knowledge structures such as taxonomy and ontology. To analyze the data, the extraction of the low level data and high level information plays a vital role in cognitive analytics. Further the fig 4.3 shows the internal components of cognitive analytics engine which comprises of knowledge representation structures, machine learning algorithm and inference engine that needed for Problem solving. The domain cognitive models help to solve the problem in cognitive style by capturing the domain specific knowledge. Learning and adaptation model component involves in improving the performance of the system by learning from the previous interactive experience from the user through API's. The primary need of using this cognitive analytics is to make a decision by generating multiple answers for the question and differentiates those answers by assigning the confidence to each answer. It uses the probabilistic algorithms to generate the multiple answers to a question, where non cognitive analytics uses the deterministic

algorithms, which gives one solution to a question. The hypothesis generation and validation component in the engine helps to compute the multiple answers required for the better decision making. IBM uses this component for generating multiple hypotheses and gathers the evidence for each hypothesis and the decision of selecting the answer to question will be based on the evidence scores of each hypothesis. The implementation of such system involves the various characteristics like the probabilistic and deterministic algorithms for cognitive analytics, since the data acquired from various sources it requires infrastructure for data cleaning and transformations and fusion, machine learning algorithm for hypothesis generation, evidence gathering and assign score to hypothesis, domain cognitive model for processing specific domain along with learning component to improve the performance and the system implementation also requires high performance computing system with characteristics like performance, scalability [8].

5. CONCLUSION

Cognitive computing consists of theories, Procedures and methodologies associated with it to design a computational intelligence system. This study discusses the six procedures in decision making in machine learning techniques, the general theories such as game theory and Bayesian theory that are used to predict the actions in decision making with set of possibilities and the methodologies like cognitive informatics which comprises of models such as LRMB where it uses seven layers starting from sensing the data from neurons in brain to transform it in to higher cognitive action process and OAR which is base for its architecture which deals the relationship between the attributes and objects and another method denotational mathematics which is the key tool for solving the real world problems. Further this study discuss on the analytics associated with cognitive computing like visual analytics where the heterogeneous data are collected from the various sources and used for visualization to make a decision and cognitive analytics in which part of data mining and visual analytics are used and the framework for conceptual level cognitive analytics along with the components such as cognitive analytics engine are discussed and also the need for these cognitive analytics is been differentiated by the way the multiple hypotheses are generated for one question unlike the non cognitive analytics where one solution is generated for a single query is discussed. Some of the challenges in implementing the architecture of cognitive analytics based on their characteristics also addressed.

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